National Aeronautics and Space Administration

NASA ADVANCED SUPERCOMPUTING (NAS) DIVISION

MODELING AND SIMULATION

The NASA Advanced Supercomputing (NAS) Division's fundamental and applied modeling and simulation capabilities, coupled with high-end computing resources, are used to develop and conduct large-scale simulations supporting critical NASA engineering and design decisions.

Benefit

High-fidelity modeling and simulation (M&S) capabilities are vital to NASA's research, engineering design, mission development, and safety efforts. NAS's specialized tools and advanced methods are enabling better understanding of the complex interactions between aerodynamics, structures, propulsion, and other design disciplines that are key to aerospace vehicle performance.

In many cases, computational modeling can also reduce the amount of experimental testing required to validate a design or measure its performance, resulting in significant cost savings and faster turnaround times for the Agency. As high-end computing capabilities grow, increased M&S fidelity enables scientists and engineers to more accurately capture the complex interactions that affect performance and to economically refine aerospace designs before they are even built and tested.

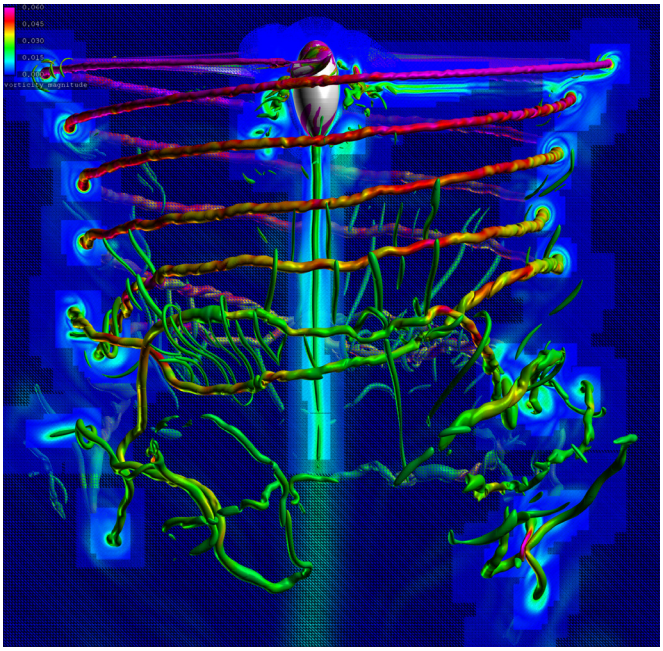
Overview

NAS modeling and simulation capabilities are playing a key role in solving NASA's most challenging science and engineering problems. Our computational fluid dynamics (CFD) experts develop and conduct advanced simulations that provide key insights and performance data for a wide range NASA's critical engineering and design efforts, from reducing aircraft emissions and noise pollution, to designing next-generation space exploration vehicles, to analyzing solar phenomena. Applying specialized codes such as OVERFLOW, Cart3D, and INS3D, and bridging any gaps with their expertise in numerical analysis, simulation, and engineering, they are able to respond to almost any M&S problem of relevance to the Agency.

Fundamental Modeling & Simulation

With a focus on advancing core M&S capabilities, NAS's Fundamental Modeling and Simulation team conducts cutting-edge, long-term research to advance numerical methods, algorithms, and codes for large-scale simulations of importance to NASA, including for future air and space vehicle design. These CFD researchers work to improve the fidelity and usefulness of computational codes supporting the Agency's endeavors in aerodynamics and fluid mechanics, as well as computational chemistry and astrophysics.

They also develop new codes and algorithms to tackle fundamental physics problems and revolutionize NASA's M&S capabilities. For example, the recently developed HyperRad software tool brings a new level of accuracy to computations of the radiative effects in hypersonic flows. HyperRad is enabling better design robustness and reduced wind tunnel and flight test costs for next-generation space vehicles, and is also proving to be extremely valuable to astronomers researching the chemical evolution of stars and galaxies.



Simulation of an isolated V-22 Osprey rotor in hover. Two levels of grid adaption improve rotor vortex resolution and predict the Figure of Merit within experimental accuracy. (Neal Chaderjian, Tim Sandstrom, NASA/Ames)

Rotorcraft Wakes

NAS is developing improved high-fidelity CFD simulation tools to help engineers reduce noise pollution and increase performance for rotorcraft design. Using the OVERFLOW 2.2 CFD code, M&S experts have made advances in rotor wake simulation accuracy. These techniques have reduced the vortex diameter error from 700% to 25%, and have improved prediction of key thrust and torque criteria for a hovering rotor to within 0.1% of the experimental value. These high-fidelity simulations provide valuable insight into the complex aeromechanics and vortex phenomena involved in rotorcraft flight.

Solar Phenomena

CFD experts are developing a detailed simulation capability that more accurately predicts the solar events that affect Earth's climate, change the stability of the ozone layer, and pose risks to NASA spaceflight missions. This cutting-edge approach includes development of complex models for turbulence, non-equilibrium chemistry, magnetic field effects, use of high-fidelity magnetohydrodynamic (MHD) simulations of sunspot active regions, and helioseismology, which enables reconstruction of the solar interior using observations of solar oscillations. High-resolution simulations, with results checked against space- and ground-based observations, help scientists to understand the sources of solar variability.

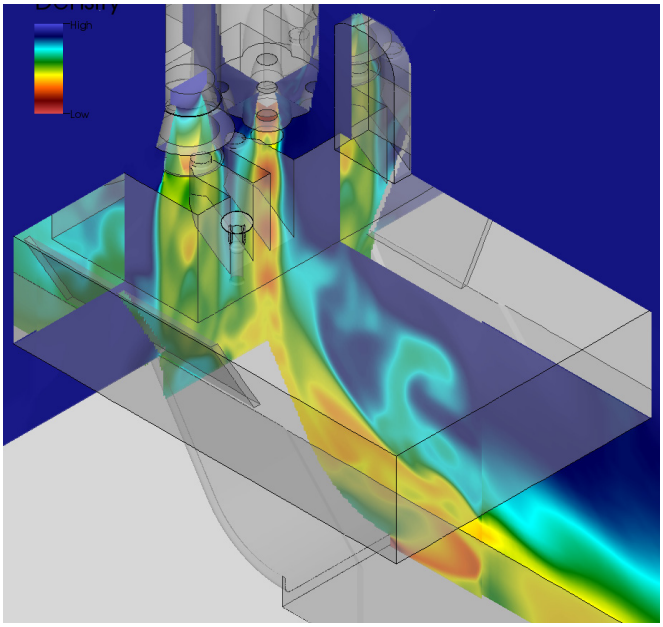
Applied Modeling & Simulation

The NAS Applied Modeling and Simulation team specializes in designing and conducting advanced simulations to support critical engineering decisions and objectives for NASA missions. Using NAS's high-end computers, this team of experts provides a wide spectrum of intensive computational analyses to quantify and understand the complex physical processes and phenomena that affect the performance of NASA systems and technologies. The team also develops and refines analysis tools and techniques to achieve an optimal balance of fidelity and efficiency for the Agency's diverse design and analysis needs.

One of the Applied M&S team's core contributions is providing extensive aerodynamic analyses of aerospace vehicles, including the Space Shuttle and the next-generation of space launch and exploration vehicles. The team also conducts simulations of environmental flow for weather modeling and optimization of green building architectures, and models circulatory system flows for human safety factors and development of biomedical devices such as the NASA DeBakey Ventricular Assist Device.

Space Shuttle Safety

NAS modeling and simulation efforts have played a crucial role in the safe return of the Space Shuttle and crew over the last seven years. For every Space Shuttle mission since 2005, NAS researchers have used their advanced M&S tools to run extensive debris transport analyses and CFD simulations of the shuttle during launch, ascent, and orbit. These analyses were crucial to evaluating the threat of debris damage from ice and foam shedding from the bi-pod ramps and external tank.



High-fidelity CFD simulation of launch environment conditions for the heavy-lift launch Space Launch System. (Cetin Kiris, Jeffrey Housman, Michael Barad, NASA Ames)

Next-Generation Space Launch & Exploration Vehicles

NAS M&S experts provide a range of simulations to support the design and analysis of NASA's next-generation space launch and exploration vehicles, including the new heavy-lift Space Launch System (SLS) and Orion Multi-Purpose Crew vehicle (MPCV). High-fidelity CFD simulations of the SLS provide detailed databases of aerodynamic flows, forces, and interactions that could affect flight performance and safety during launch. This data is used to compare alternate candidate designs, perform structural analyses, and optimize vehicle shape and trajectory.

Crew vehicle simulations analyze stability and control during launch aborts, plume effects and interactions from the abort motors, and other critical aerodynamic and aerothermal performance factors during atmospheric entry, descent, and landing. These simulations provide key performance data for conditions that are difficult or impossible to obtain using ground-based or flight testing.

NAS experts are also developing new CFD tools and techniques to simulate launch environments for the heavy-lift SLS, which will be even more intense than those generated by the Space Shuttle's 7 million pounds of thrust. These analyses predict critical pressure loads and acoustic noise levels during ignition and liftoff to assess the suitability of existing launch facilities for larger vehicles, and to ensure that excessive vibrations will not damage their valuable payloads.

Background

The NAS Division's world-class modeling and simulation capability is built on a tradition of expertise in aeronautical engineering and its core research areas, including aerodynamics, aeroacoustics, advanced computational and mathematical methods, and experimental techniques.

Throughout its history, NAS has been a leader in developing and advancing high-fidelity modeling and simulation technologies. Many of the sofisticated codes used to support critical work for the Agency, including CART3D and modules in OVERFLOW, were developed at NAS. These codes continue evolving to match technology advances, and remain vital to NASA missions today.

For more information on NAS Division activities, please visit: www.nas.nasa.gov

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